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ABSTRACT

Today, faced with the problems of global competition, increasing costs, and complex production engineering, a company can only be successfully managed if the employees are motivated and highly qualified. To cope with this demand the new educational scheme for cost-effective retraining, lifelong learning and distance education at the workplace should be introduced. This paper describes the developed Web-based Intelligent Training System used in the Bosch WebTr@iner product range. It details how Java simulation, virtual reality modeling, and animation can be used in a complementary approach to teaching complex industrial processes and systems in cost-effective, rapid and interesting way on the global scale. (Author)

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Advanced Interactive Web Technologies in Industry Training

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Abstract: Today, faced with the problems of global competition, increasing costs, and complex production engineering, a company can only be successfully managed if the employees are motivated and highly qualified. To cope with this demand the new educational scheme for cost-effective retraining, lifelong learning and distance education at the workplace should be introduced. This paper describes the developed Web based Intelligent Training System used in the Bosch WebTr@iner product range. It details how Java simulation, virtual reality modeling and animation can be used in a complementary approach to teaching complex industrial processes and systems in a cost-effective, rapid and interesting way on the global scale.

Introduction

Over the last decade, a dramatically increased rate of change in business has been observed. Companies are struggling to keep pace with new competitors that are introducing products at an incredible rate. The technological innovations and cycle are becoming shorter and the current technology will be obsolete and replaced by new advanced technology within a few years. But this increased rate of product introduction and the shorter technological cycles has created a huge problem. First of all there is demand for a higher level of knowledge to cope with the "scientification" of industrial branches based on advanced technologies, which

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should be provided for greater number of employees. This demand is even stronger in correlation with the fact that technology is getting younger simultaneously as workforce is growing older and globally dispersed.

Specifically, companies are being challenged with how to enable employees and the channel to sell and support the products that are flying off the assembly line. As a consequence of this fast development, there is no doubt, that retraining and lifelong learning of engineers, technicians and workers from industry is becoming a necessity (Schmockel, 1998). To maintain their innovative forces in the future, highly qualified experts with a multidisciplinary background, experimental skills and social attitude must be educated (Donovan, 1999).

The ever-growing importance of knowledge and greater numbers of people being educated and trained at the high level has increased the responsibility of educational institutions. Governments and industry are under tremendous pressure to convey more and more knowledge and skills at ever-faster rates to growing number of persons in need of education and training. But the costs involves for such rapidly growing demand is reaching proportions, which can no longer be financed even by the industrialized nations with conventional educational and training methods.

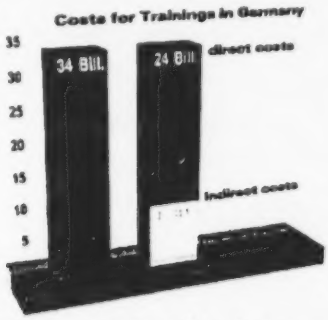

Figure 1: Costs for training in Germany

The diagram of Fig. 1 (see Hyperwave, 2000) shows how the total expenditure for training in Germany compares to the direct and indirect costs of training. Of the billions spent in this area, on average only about a fifth is spent on costs that directly relate to the training course. In fact, it is indirect costs (travelling and accommodation expenses for example) that make up the rest of the outlay. Often, the hidden cost of temporarily replacing staff is overlooked. Worse, staff may not actually be replaced during the time they are absent for training. The business is, therefore, operating in a much less efficient way.

What these estimates show is that traditional methods for training are not proving cost-effective. Although the diagram is for a specific country, it is highly probable that the situation is the same in practically any location.

To face the above-mentioned topics and develop new paradigms for learning, the contents, methods and forms have to be changed to fulfil the growing personal needs for a higher level of knowledge in new specialization and skills. To cope with this demand the new educational scheme for cost-effective retraining, lifelong learning and distance education at the workplace should be introduced.

The e-Learning tools accessible via Internet/WWW technologies create a very good environment to solve this complex task. By providing a solution that overcomes the challenges of proximity and time, e-Learning is a vital component in succeeding in business today. Wolz (see Wolz et al., 1997) have investigated the use of computer-mediate communications in educational environment. Maurer (Maurer and Dietinger, 2000) have described how modern WWW systems support teaching and learning.

Considering these facts, it is particularly in the automation sector that tailor-made vocational and specialized training has advanced to become one of the decisive criteria for success. And this is where Bosch AT-didactics comes in with its unique training program (Bosch AT-Didactic, 1999).

The paper describes the structure of the developed Web based Intelligent Tutorial System (ITS), used in Bosch WebTr@iner product line. It details how Java simulation, virtual reality modeling (VRML) and animation can be used in a complementary approach to teaching complex industrial processes and systems in a cost-effective, rapid and interesting way on the global scale. The target audience, for which the WBT is designed, is sales personnel and technicians. Through the WBT they should gain a better understanding of the advantages of the range, which should contribute to improving the sales for the sales personnel and technical knowledge for the technicians.

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Learning Objectives

It has been the authors' ambition to design Web based courses in accordance with the model for "independent learning", with a particular emphasis on the interaction with the course material. The Web based trainers should guarantee opportunity for:

- Life-long, independently responsible learning;
- Motivated learning;
- Self-determination/autonomous learning (learning time, learning methods, learning tempo and possibly even subject matter have to be determined to a grate extend individually)
- Training on Demand (Learning will no longer take place only in the classroom or the laboratory. The training will go to the trainee, to his workplace, his office in the company or privately at home.)

Experience has shown that the effective development of training concepts and materials require a clarification of various learning objectives. It is useful to distinguis h the different groups of goals since it is important that each group be matched with the appropriate didactical procedure (IWL Martens, 1999). We distinguish between learning objectives, in which experiments and hands-on experience are of prime importance, other learning objectives for which a visualized and clear presentation is decisive, or learning objectives that depends on video or films to reach the feeling of the learner.

Multimedia program is designed to reach the following learning objectives:

- Developing positive attitudes towards personal effectiveness;
- Recognizing the possibilities of influencing difficult situations;
- Accepting difficulties as challenges;

The learners have to be trained with extensive hands-on experiments to strengthen further understanding of theory. The idea is to illustrate all theoretical concepts with examples selected from real-world applications, in order for learners to benefit from the practical experience and to help them understand links between theory and practice. The experience side of e-learning should address factors including:

- Engagement: How will we get the learner fully engaged?
- Curiosity: How will we harness the power of curiosity and exploration?
- Simulation and Practice: More powerful simulation and practice opportunities?
- Action Learning: Simulators that trigger action learning and align with workplace challenges?
- Intensity: How can we create high intensity, memorable learning experiences?
- Assessment and Feedback: Help the learner to gain a better sense of their knowledge gaps?

In using interactive media the learner is required to repeatedly solve complex tasks and thus is actively involved and at the same moment is demonstrating mastering of material. Further, the results of short follow-up tests should show to what extend the learner is personally affected by the content of the presented material. Self-evaluation will make progress visible to the learner, and help to decide when to proceed in the material.

The learning methodology, implemented in the WebTr@iner, is designed to maximise the impact of modern multimedia technologies and human-computer interaction to achieve high quality training, which is attractive to the student. The approach used aims to place the onus of learning on the students' own initiative. Based on his/her own knowledge and experience, the student is able to choose the appropriate route through the course material, and in turn this improves his/her motivation during the learning process. This requires the course material to be structured into essentially independent modules, freely accessible in whichever sequence is desired.

WebTr@iner Series

The WebTr@iner series consists of several educational courses, which have been developed in Web technology. All modules are directly accessible by the WWW browser. The network version may be directly run on a Web server, so networked learning and distance learning via Internet and training servers has become reality. The WebTr@iner is suitable for autodidactic learners who want to familiarize with a subject as well as for trainers aiming at lively multimedia-supported classes.

Several e-Learning tools are available: Hydraulics-Basics; Hydraulics-HS2, Electro Hydraulics; Pneumatics-Basics; Pneumatics-Controls, Continuous Control Hydraulics. All systems are modular in concept and can therefore be directly adapted to specific requirements. They can be extended and combined with each

other at any time and in accordance with the learners' wishes. By personalization of course content based on the personal skill of a targeted individual Role Based Training is ensured.

Above all, effective learning is based upon the quality of the training and the training system as well as upon practical exercises. The varied design of the WebTr@iner series including quality images, graphics and sound-videos ensures an interesting training course and facilitates knowledge transfer. Trainers comprise an intuitive user-friendly interface, a convenient navigation system; a modular architecture; a proper ratio of text material and animations.

An environment for *learning by doing* on the basis of developed interactive tools and *learning by discovering* based on the simulation of real systems are provided. The developed Web trainers offer a virtual classroom experience that combines the benefits of traditional classroom training with the flexibility of **e-Learning** in order to increase learning with high moment of teaching value.

WebTr@iner Structure

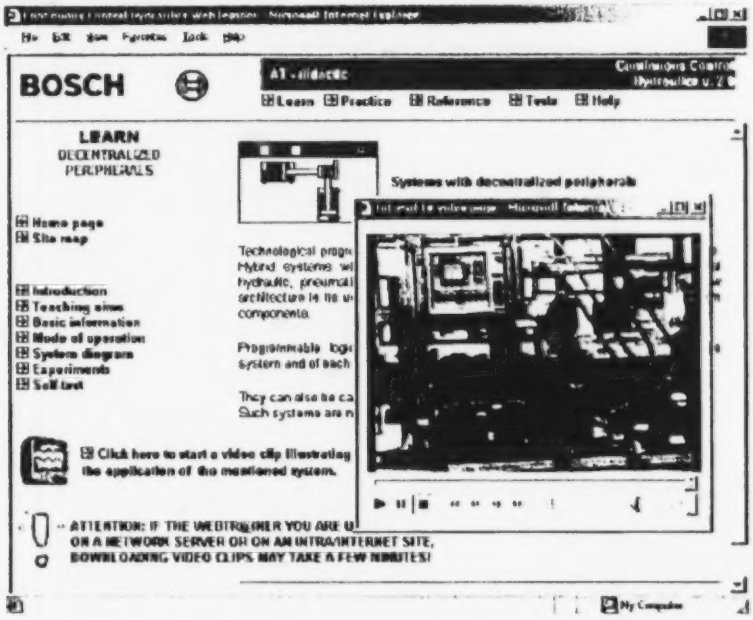

Figure 2: Basic information page of the WebTr@iner

All tutorials have a common structure (Fig. 2) build around the aim to offer a learner-centred environment, in which the learners are actively involved in the learning process. Generally the WebTr@iner structure has **Learning**, **Practice** and **Test** sections. Advanced Web technologies and methods, which encourage learners participation are used to the maximum extend in all sections.

A **video clip** shows practical application of the considered component or system in industry or real life.

Mode of operation is illustrated by 3D animated model. Animation is a particularly valuable technique when it illustrates phenomena, properties, and any topics, which cannot be effectively described by static published lecture notes. High degree of animation and interaction are of crucial importance to the presentation. Interactive animations provide insight into the inside of component and illustrate its functionality.

After the consumption of the individualized training unit, the trainee gets the chance to practice the newly obtained knowledge. A **virtual reality** play model is provided to visualise the functions and flow characteristics of hydraulic or pneumatic components. Virtual reality models of components are a good opportunity to bring more transparency into dynamic processes occurring into the component during its operation.

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Practical training via **interactive simulators** can contribute considerably to an easier and deeper understanding of the learning material. In systems simulations, the trainee may apply the newly gained theoretical knowledge to entirely risk free practical solutions and trace the interaction of components. **Guided experiments** are also provided in which learners should follow step-by-step instructions of virtual tutor. Correctness of learners' actions is checked at every step.

The evaluation of the gained knowledge and assessment of the level of understanding are the natural accompanying measures of the self-learning process. **Tests** are a special kind of interactive learning. The test questions are designed in a way to illustrate as clearly as possible what the learners are expected to learn and which aspects are more important than others.

Interactive Tools

A better understanding of the physical, electrical, and mechanical properties is strongly desirable, because of the increasing complexity of today's industrial applications. This is not possible without hands on experience. For this reason practical training is very important. The skills obtained through problem solving are a strong contribution to the introduction of learners to the behavioural patterns of today's industry.

Assembly Unit

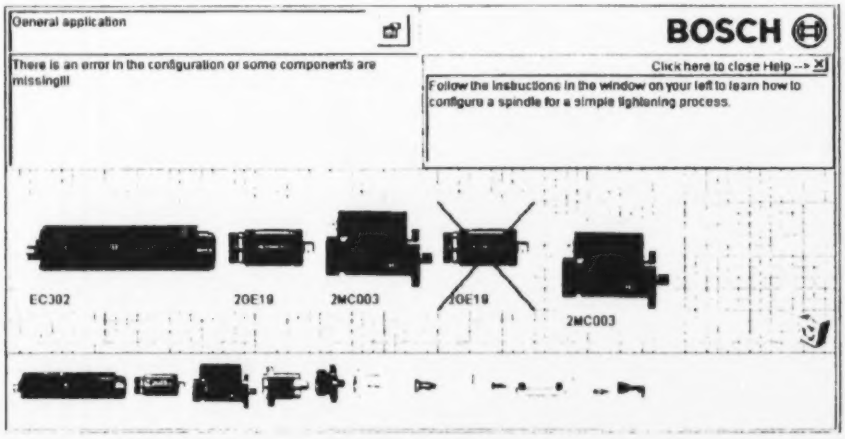
General application
BOSCH
There is an error in the configuration or some components are missing!!!
Click here to close Help -->
Follow the instructions in the window on your left to learn how to configure a spindle for a simple tightening process.
EC302
2OE19
2MC003
2OE19
2MC003

Figure 3: Java based interactive assembly tool

The assembly unit is developed as a general-purpose interactive tool for assembling different systems from the predefined set of components. Users can interactively choose every one of components and move it to the right place in the system, which should be assembled. Checking facilities and context sensitive on line help are provides as well.

The tool has three regimes called "show me", "guide me" and "try me". The first shows the right way of assembling the system being on consideration as well as sequences of user actions that should be done for obtaining such result. These sequences include choosing appropriate component for placement, moving it to the right position and placing there, choosing the next one etc. The second regime like an intelligent "virtual tutor" guides users step by step during assembling. In this regime incorrect actions are prevented and the user can start placement of the next component only if the previous one has been placed to the right position in the system. The wrong component and the wrong position are disabled for using. The third regime allows for free placement of every component at every position in the system. The Check facility is intended to show users correctness of their actions. All obtained errors are marked on the screen and an appropriate report is provided to the user. Fig. 3 shows the user interface of the interactive assembly tool and the result from checking of the current system configuration.

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System Simulators

Technological progress has led to new approaches to complex production processes. Hybrid systems with open system architecture have replaced traditional hydraulic, pneumatic and electric systems. They link and control all system components. Such systems are mainly used in high technology environments. Their proper operation need appropriate maintenance staff, which should have a firm understanding of the whole system.

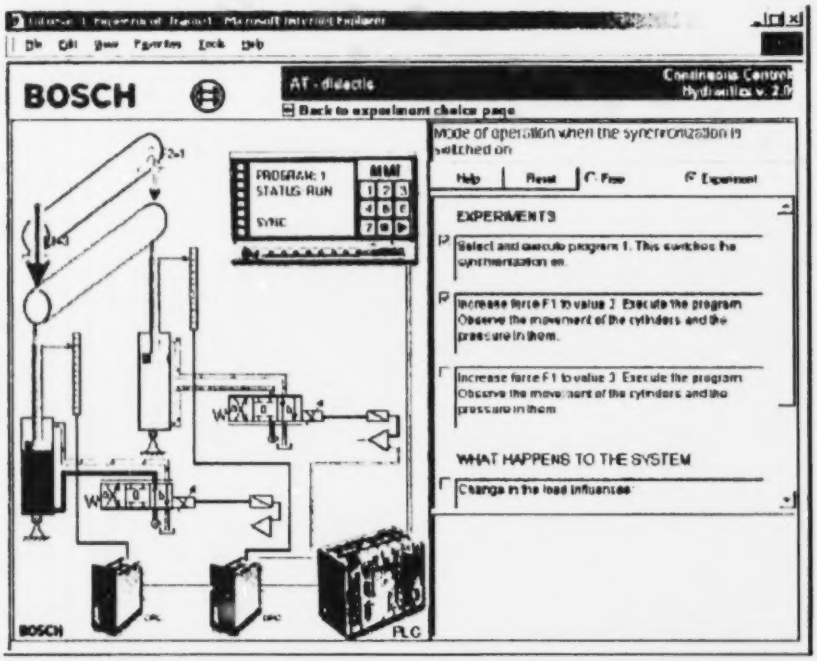
BOSCH
AT - dielectric
Continuous Control
Back to experiment choice page
Mode of operation when the synchronization is switched on
Help
Reset
Free
Experiment
EXPERIMENTS
Select and execute program 1. This switches the synchronization on.
Increase force F1 to value 2. Execute the program. Observe the movement of the cylinders and the pressure in them.
Increase force F1 to value 3. Execute the program. Observe the movement of the cylinders and the pressure in them.
WHAT HAPPENS TO THE SYSTEM
Change in the load influences
PROGRAM: 1
STATUS: RUN
SYNC
MMI
BOSCH
PLC

Figure 4: Java based system simulator

It is very important learners to have opportunity to obtain hands-on experience working with the system. It is not common practice in industry to stop technological process and to use production system for education. This is also very risky, because using product equipment by unqualified learners can easily lead to personnel hazards and material damages. For this reason interactive simulators are very useful for training. They provide the learners with an easier and better understanding of complex problems using simulation to animate various properties, operational principles and phenomena.

Fig. 4 shows an interactive Java based simulator of one Bosch continuous control hydraulic system with decentralized peripherals. Programmable logic controls (PLC) ensure predefined functionality of the whole system and each individual component. The system can perform different operations depending on the program incorporated. By clicking on the man-machinery interface (MMI) unit users can change the program and observe the signal sequences, interactions between different components in an automated system, sensors reaction and corresponding action of the robot and other equipment in the production line. All dynamic processes are visualised by changing colours for signal sequence, sensors and different fluid pressures. Animations are used for a products flow on the product line, robot hand movement and cylinder rod movement for current forming operation. Changing the program will change the PLS command and the same equipment will perform quite different operations. For educational purposes the main component of the system appears in the screen in the same manner as in real production process.

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Intelligent "Virtual Tutor"

In the previous section the so-called "free experiment mode" of the interactive simulator was considered. "Guided experiment mode" is also provided. To increase teaching value in the tutorial an intelligent "virtual tutor" is used in guided experiments. The idea is to stress learners' attention on important topics, on specific features of the system, on critical operations or on required sequence of operations, which should be performed for guaranteeing error-free mode.

There are two experiments per tutorial, which force learners to follow step-by-step instruction to complete the experimental task. This "virtual tutor" not only guides learners, but at every stage checks if they have properly performed the task. If not, the next step is disabled. On line help is also provided on request.

Fig. 4 illustrates the free and experimental modes of the simulator. In free mode all the controls are accessible. During the experimental mode all controls are disabled except the particular one needed for that task.

After successfully completing the guided experiment the learners are requested to answer two questions in order the "virtual tutor" to check if they have understood the system's mode of operation. Learners obtain on-line feedback of correctness of their answers.

By becoming an active part of the learning process, the learner is involved in a self-organised discovery process. Thus he/she can learn not only the basic properties and processes, but also acquire a better and deeper understanding of the analysed subject.

3D Virtual Reality Models

Virtual Reality Modelling Language (VRML) is used for 3D representation and simulation of dynamic technological processes. The created virtual environment gives the user opportunities to play and experiment risky-free with complex machinery, to take a look inside the different components, to learn about their controls and adjustment procedures.

Most of the 3D models have at least two different representations, each one with a different level of details. Depending of the proximity of the user to the component, a more or less detailed model is visualized. Cross-sectional models help for better understanding of how the components work Components can be rotated and examined from any direction; the paradigm of "Walk" and "Fly" is used to navigate in a complex environment. A mathematical model is used for calculations of output pressure and flow rate according input values and user presets and adjustments at run-time. This permits complete hydraulic/pneumatic schemes to be composed and simulated by linking together inputs and outputs of different components.

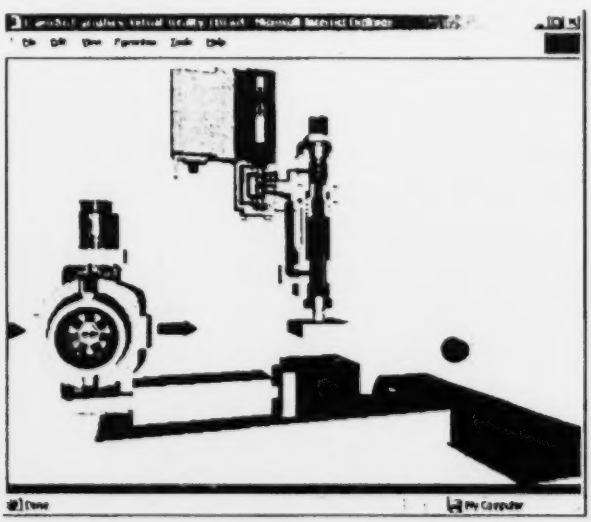

Figure 5: VRML 3D model of the decentralised hydraulic peripheral system

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Fig. 5 illustrates an automated system composed of hydraulic press, robot application and a transfer system. The changes of flow rate and pressure in a continuous controlled hydraulic system with a **variable displacement pump,** 4/3 Direct Control Valve (DCV) and a double acting hydraulic cylinder are examined. The model helps to illustrate the relationship between needed press power and displaced volume by the hydraulic pump.

A program, simulating a Programmable Logic Controller (PLC), drives the action sequences from the press, robot and the transfer system. The VRML model and the Java-based PLC Simulator are linked via the External Authoring Interface (EAI).

This approach allows for the creation of free-programmable virtual environment. It can be used for simulation of different technological processes only by changing the program, interpreted by the PLC Simulator.

Conclusions

Training and enhancing the skill and expertise of personnel is imperative. But the complexities of today's fast paced business environment make effective training and continuous learning a challenge at best. That is where **e-Learning** will provide its benefit.

This paper describes an intelligent interactive **e-Learning** system for teaching hydraulics and pneumatics. In addition to theory, it includes:

- Video clips illustrating the basic application of the system;
- Many animated pictures showing components' mode of operation;
- Virtual 3D play models of the basic components;
- Interactive assembly unit, for system assembly from predefined set of components;
- Interactive system simulator demonstrating different modes of operation;
- Intelligent "virtual tutor" guided experiments
- Self-tests.

The main advantages of the proposed intelligent WebTr@iner can be summarised as follows:

- The teaching method used illustrates complex processes in an easy, clear and attractive manner;
- It takes into account the different levels of knowledge of students starting the course;
- As an Intelligent Tutorial System it reacts to the students' capabilities and mistakes;
- It is quickly accessible, easy to update and distribute;
- Widespread geographical areas will not cause a logistical problem.
- It provides a time and cost effective training of users;
- WebTr@iner is available in various languages;

The implementation of the Intelligent Training Courses and modules on the Internet/WWW allows the sales personnel and technicians to work autonomously at any time and at any site. Together with the didactic department of Bosch Automation a system was developed to easily train staff worldwide. The ITS approach offers scope of application in training curricula that similarly require complex and global solutions i.e. corporate management or sales training as well as electrical and mechanical engineering. Distance education through network offers tremendous opportunities not only for continuing education but also for education in general to break the barriers of place and time that otherwise limit access to teaching.

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